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ABSTRACT

Previous research has provided support for the mediating role of self-efficacy between independent attitude variables and dependent performance measures. However the existence of a confirmatory model, that can be generalized over both males' and females' measures of attitudes, perceived self-efficacy, and achievement levels, has not yet been reported. The study reported here was an attempt to propose a simple structural model involving mathematics achievement accompanied with tests of its robustness and generalizability to both sexes. Participants included 117 male and 108 female students from 12th grade algebra classes. who were administered the Mathematics Achievement Test (MAT) and the following three rating scales: the Mathematics Self-Efficacy Scale (MSES), the Mathematics Attitude Inventory (MAI), and the Mathematics Attitude Survey (MAS). Course grades, as assigned by the teachers, were also used as an independent variable. LISREL analyses specified mathematical self-efficacy as a significant mediator between measures of mathematical attitude and mathematics achievement with an excellent goodness-of-fit statistic for both males and females. (31 references) (JJK)

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Gender Similarities in a Structural Model of Mathematics Achievement¹

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Abstract

A structural model of mathematics achievement was tested involving 117 male and 108 female high school seniors. Two attitude measures, three mathematics self-efficacy scales, and a mathematics achievement test were administered in the same order to all the subjects. Teacher-assigned marks in a selected mathematics course the subjects were taking were also obtained. The covariance matrices of males and females were analyzed using a two-group LISREL procedure. The LISREL model specified mathematics self-efficacy as a mediator between mathematics attitude and achievement. The postulated model was an excellent fit to the data for both males and females.

Gender Similarities in a Structural Model of Mathematics Achievement¹

The present study examines the role of self-efficacy as a mediator between attitudes and achievement in mathematics. A self-efficacy perspective to the understanding of performance on specific tasks is well documented (Bandura, 1986; Campbell & Hackett, 1986; Hackett & Betz, 1989; Norwich, 1986; Relich, Debus, & Walker, 1986; Siegel, Galassi, & Ware, 1985). Bandura (1977; 1982) postulated that self-efficacy expectation of an individual concerning the ability to perform successfully a given task is a reliable predictor of whether the individual will attempt the task, how much effort he/she will spend, and how much the individual will persevere in pursuing the task in the face of unforeseen difficulties. Also, an individual's perceived self-efficacy influences and is in turn affected by cognitive styles and preferences, arousal, and task performance outcome (Bandura, 1986). Correlational and path-analysis studies have provided initial support to the mediating role of self-efficacy between attitude variables as an exogenous variable and a mathematics performance measure as an endogenous variable (Norwich, 1986; Relich, Debus, & Walker, 1986; Siegel, Galassi, & Ware, 1985). A confirmatory model, that can be generalized over males' and females' measures of attitude, perceived self-efficacy, and achievement, has not been reported. The present study proposes a simple mathematics achievement structural model and tests its robustness and generalizability for males and females.

Hackett and Betz (1989) reported that mathematics performance and achievement and mathematics self-efficacy measures were significantly and positively correlated with attitude toward mathematics and mathematics-related major. Also, results of their hierarchical regression analysis showed that mathematics self-efficacy was a more robust predictor of the choice of a mathematics-related major than mathematics achievement and performance variables. Theoretical predictions from the self-efficacy theory would, as they stated, most probably suggest such a strong link between the choice behavior of individuals and how confident they feel about their perceived ability and competence in

the subject. Still, a theoretical gap exists. It is not clear whether generalized perceived self-efficacy would mediate between attitude toward mathematics and achievement in mathematics. We view that theory should have both specific validity and general validity. In this regard, self-efficacy theory is not an exception. It should hold both for (a) individuals' specific attributions of competence and their performance on the related tasks, and (b) individuals' general attributions of competence and their general performance in the area of competence. We propose to test the mediational role of generalized self-efficacy perceptions of individuals between their attitude toward mathematics and their general mathematics achievement.

Several studies showed the viability of the self-efficacy theory in situations where self-efficacy perception of a specific task related significantly to the subsequent performance on a similar task (Bandura, 1977, 1982, 1986; Hackett, Betz, O'Halloran, & Romac, 1990; Norwich, 1985). Also, the effects of experimental manipulation on both self-efficacy and task performance were according to theoretical prediction (Bandura, 1972, 1982, 1986; Schunk, 1982, 1983; Schunk & Hanson, 1985; Schunk & Gunn, 1985, 1986) such that as self-efficacy perception improved so did the performance on the related measure. Nevertheless, confirmatory evidence on the mediational role of the general components of self-efficacy perceptions of mathematics between attitude toward mathematics and general mathematics achievement is not available. The present study proposes to test such a model and to test whether the component parameters of the model are similar for males and females.

Proposed Structural Model

To test a structural model it is important that the manifest indicators (observed variables) of the latent variables used have reasonable reliabilities so that the parameter estimates from the model are from robust measures of the variables of interest. Otherwise, the analyzed covariance or correlation structures depart significantly from the true estimates. Without reasonable reliabilities of the variables involved, correlations

among the variables are under- or over-estimated and the corrected (attenuated) correlation values would depend upon the true reliabilities of the variables concerned. This consideration dictated that we use composite variables in the postulated model, instead of the subscale scores of attitude and mathematics achievement measures. The self-efficacy subscale scores were used because each of these scales had an internal consistency larger than .85.

Figure 1 gives the proposed structural model. The components of this model are based on the studies involving mathematics-related course choice and associated variables using path analysis (Hackett, 1985; Relich, Debus, & Walker, 1986) and structural modelling (Meece, Wigfield, & Eccles, 1990). In our model the first predictor variable is the composite score on the Mathematics Attitude Survey (MAS). This instrument measures students' self concept, locus of control, attitude toward mathematics, sex-role orientation, and family orientation. As mentioned earlier, because the subscales have very low reliabilities and to avoid the problem of multicollinearity, the composite score of MAS was used as a manifest indicator of the predictor latent variable, attitude toward mathematics. The second predictor is the composite measure of students' perception of their mathematics teachers, anxiety, ability, enjoyment, and motivation. It was measured by the Mathematics Attitude Inventory (MAI) and was used as an alternate measure of attitude toward mathematics (predictor latent variable). This exogenous latent variable is linked to the two latent endogenous variables, mathematics self-efficacy and mathematics achievement, respectively. The manifest indicators of the first latent endogenous variable (Mathematics Self-efficacy) are the Mathematics Self-Efficacy (MSES) subscales, Courses (CS), Problems (PS), and Daily (DS). Course grade (ALG), and the Mathematics Achievement Test (MAT) scores are manifest indicators of the second endogenous variable (Mathematics Achievement). A direct path links Mathematics Self-efficacy to Mathematics Achievement.

Insert Figure 1 about here.

Method

Sample

The sample consisted of 225 (117 male and 108 female) high school students enrolled in nine Algebra 30 classes (an academic grade 12 course) in three high schools from two different school jurisdictions in a medium-size city in mid-western Canada. For both males and females, the age range was from 17 to 19 years and the average age was 17 years and 5 months. Students taking Algebra 30 generally have intentions of attending a post-secondary institution after completing the high school graduation requirements. Accredited teachers teaching high school courses have the sole responsibility of assigning a course grade. Students of non-accredited teachers assign 50% of the mark in a grade 12 course and the other 50% is based on a provincial test administered after the course. Admission to a provincial university is based on the average mark on a specified set of high school courses, depending on the program a student plans to enter. All the mathematics teachers of the students in the sample were accredited.

Instruments

A mathematics achievement test and three rating scales were used in this study. Besides the scores yielded by the instruments, teacher assigned grade of each student in Algebra 30, expressed between 0 to 100, with 50 as the minimum passing mark, was used as a manifest measure of mathematics achievement.

Mathematics Achievement Test (MAT). A 40-item test was developed for this study to measure achievement in algebra of Grade 12 students. Its preliminary forms were pilot tested on 135 students. Four teachers teaching Algebra 30 were consulted on the content validity of the proposed items. Items judged inappropriate were revised or

discarded. In the final form, each item was categorized along two dimensions, the cognitive level dimension and the content area dimension. The cognitive level categories, arranged in ascending order of cognitive complexity, were: (1) identification of concepts, (2) computation, (3) comprehension of concepts, (4) application and problem solving (Begle & Wilson, 1970; Bloom, 1956). The content areas were: (1) number and sets of numbers; (2) powers and radicals; (3) polynomials; (4) solving equations and inequalities; (5) systems of equations, and (6) functions, graphs, and variations.

The total score on the MAT test was used as the second manifest measure of mathematics achievement. The α reliability of the test was .77 and the average item difficulty was .42.

Mathematics Self-Efficacy Scale (MSES). The Mathematics Self-efficacy Scale (modified from Betz & Hackett, 1983) measured students' self-efficacy in performing everyday math tasks (Daily Subscale, DS), solving math academic problems (Problems Subscale, PS), and completing mathematics-related high school courses (Courses Subscale, CS). Students indicated their confidence on a ten-point scale, ranging from "No confidence at all" to "Complete confidence". The α reliabilities of the Daily, Problems, and Courses subscales were, respectively, .88, .89, and .92.

Mathematics Attitude Inventory (MAI). The Minnesota Research and Evaluation Project Team (1972) developed the Mathematics Attitude Inventory. Its 48 items measured students' attitude toward mathematics in terms of the underlying factors: perception of their teachers; anxiety; value in society; perception of their abilities; enjoyment; and motivation. Students indicated whether they strongly agreed, agreed, disagreed, or strongly disagreed with each statement. The α reliability of the total MAI scale of 48 items was .81. Only the total score was used as a measure of attitude toward mathematics.

Mathematics Attitude Survey (MAS). The Mathematics Attitude Survey (modified from Ethington & Wolfe, 1988) assessed students' self concept, locus of control, attitude toward mathematics, sex-role orientation, and family orientation. It consists of 23 statements. Students indicated whether they strongly agreed, agreed, disagreed, or strongly disagreed with each statement. The α reliability of the total MAS scale was .75 and the total score on this instrument was the second measure of attitude toward mathematics.

Procedure

Students who were willing to participate provided data in three regular class periods in late 1989. In the first session, students were given 50 minutes to write the MAT. They were allowed to use calculators. During the second session, students completed the MAS and the MSES in about 45 minutes. In the last session, students completed the Mathematics Survey II (a questionnaire that elicited the background characteristics of the students and data from this instrument are not used in the present study) and the MAI in about 40 minutes.

Analysis

Data were analyzed initially to examine the descriptive statistics for each item and the composite scores on each instrument or scale. No outliers were found and the total scores of each of the six measures and of the Algebra 30 grade (ALG) were found to be distributed approximately normally. Then the reliability analysis, as reported above, was carried out. The correlation and covariance matrices for the seven input variables for the total sample as well as for males and females for the structural model analysis were computed. The covariance matrix for each group was used to perform maximum likelihood linear structural relations analyses. For these analyses the LISREL 7 program (Joreskog & Sorbom, 1989) was used. Generally, a covariance matrix is used for structural modelling.

When the hypothesized structural model was analyzed using the covariance matrix of the total group ($n = 225$) the goodness-of-fit index (GFI) of .951 and the adjusted GFI of .875 were obtained. The $\chi^2 (11) = 43.75$, $p \leq .05$ further indicated that the specified model was only a modest fit to the data. For this model, the modification index of one of the manifest observed variables, DS, was 26.65. This suggested an evaluation of the specified model because introducing a new parameter could reduce substantially the value of the χ^2 . The parameters of this model for the total group are given in Figure 2.

 Insert Figure 2 about here.

We examined the modified model for parsimony, which in structural modelling is considered as an important criterion for adopting a competing model when it can be rationalized by precision of estimation of its parameters (Bentler & Mooijart, 1989). This meant that a path from the achievement latent variable to the DS was introduced. The modified model is shown in Figure 3. Parameters for structural modelling for the total group and females and males were estimated using this model. Covariance matrices for males and females were analyzed using a two-group approach in which the parameters of the females' structural model were estimated when specified similar to those for the males' model. We also tested the equivalence of the covariance matrices of males and females using LISREL 7.

 Insert Figure 3 about here.

Results

Descriptive statistics and a correlation matrix for the seven variables for the total group are given in Table 1. As shown in the table, all the observed correlations were significant at the .05 level.

 Insert Table 1 about here.

Means, standard deviations, and intercorrelations of the seven input variables for males' and females' data are given in Table 2. All the correlations for males as well as for females were significant ($p \leq .05$). Furthermore, the means of males on CS, PS, DS, and MAT were significantly higher than those of females ($p \leq .05$). Meece, Wigfield, and Eccles (1990) reported similar differences. Kimball (1989), in a review article, cited numerous studies that showed that males in high school grades generally achieved higher than females on standardized and unfamiliar tests whereas on teacher-made tests or on course grades either there were significant differences or the differences that were observed favored females. Randhawa (1991) showed, in three different samples of grade 10 students over a span of 11 years, consistent male advantage over females. Hyde, Fennema, and Lamon (1990) reported differences in favor of males but showed that the effect size had decreased over the years.

 Insert Table 2 about here.

Path coefficients of the modified structural model for the total group, males, and females are given in Figure 4. The completely standardized solution values for the total group data are above the arrows. On the other hand, the common metric completely standardized solution parameter values from a two-group solution are given below the arrows. All the parameter estimates were significant ($p \leq .05$) in all three structural models tested. The GFI's were .986, .984, and .970 for the models for the total group, males, and females, respectively. The GFI of 0 indicates total lack of fit of the model whereas the GFI of 1 indicates that the specified model fits the data perfectly. Moreover, for the total group solution, the χ^2 test also confirmed that the specified model was

satisfactory, $\chi^2(10) = 11.84$, $p > .05$. The adjusted GFI is a simple function of the GFI. It takes into account the degrees of freedom of the model. For the total group structural model the adjusted GFI was 0.96; this is a further indication of the goodness-of-fit of the model. The two-group solution was also found to be a good fit to the data, $\chi^2(20) = 18.71$, $p > .05$.

 Insert Figure 4 about here.

In the modified and best fitting model the DS as one of the manifest indicators of the math achievement construct had the path coefficient of -.44. Other path coefficients were all positive.

The only parameter estimate on which there was a significant ($p \leq .05$) gender difference was the MAT. The other four parameter estimates, MAS, ALG, PS, and DS error terms, which had apparent differences for the two models were not statistically significant. Therefore, the structural models of males and females were almost similar. These structural model solutions support the hypothesized role (mediational) of the self-efficacy construct. Also these models for males and females could be considered similar in spite of the observed significant differences in means on the self-efficacy measures and the MAT.

The test of the equality of covariance matrices of males and females was affirmative [$\chi^2(28) = 24.86$, $p > .05$]. This was further confirmed by the GFI's of .966 and .960 for the males' and females' covariance matrices, respectively. Other results for the structural modelling are reported, therefore, only for the combined group.

Table 3 provides squared multiple correlations and intercorrelations of the latent variables. A substantial proportion of the variance (53%) in math achievement was predictable from the model. Mathematics efficacy had 46% common variance with mathematics attitude. The three pairs of correlations among the structural variables were

substantial and statistically equal. Therefore, self-efficacy and attitude each has almost similar predictive power of math achievement. With self-efficacy as a mediating variable in a plausible structural model, predictive efficiency increases by 7.2%.

 Insert Table 3 about here.

The total coefficient of determination of the structural model was 0.55 and that of the dependent and independent manifest indicators was 0.98 and 0.73, respectively. This evidence suggests that the structural model not only is a good fit to the data but it also has a sufficient degree of determinability, especially for the dependent manifest indicators, which is close to 100%. Thus, these results demonstrate for the proposed structural model the mediating role of mathematics self-efficacy.

It is possible that the attitude construct serves a mediating role in the model. This model was tested. The $\chi^2(11) = 43.75$, $p \leq .001$ indicated that it was not a good fit to the data. Furthermore, though the GFI was 0.951, the adjusted GFI was 0.875. Hence, the alternate model did not fit the data as well as the model advocated herein.

Discussion

The results of the present study demonstrate that math self-efficacy is a mediator variable between math attitudes and math achievement. Because the alternate competing model (which did not follow from a theoretical perspective), in which the mediating role of math attitudes between math self-efficacy and math achievement was tested, was not a satisfactory fit to the data provides conclusive support to the viability and validity of the model. Also, the model is generalizable to both males and females. Thus, our results, using a confirmatory test of the model, extend the application of the self-efficacy theory beyond task specific situations (Bandura, 1977, 1982, 1986; Hackett, Betz, O'Halaran, & Romac; Norwich, 1985).

In the two-group solution, the hypothesized structural model, with the self-efficacy as a mediator, fit the data of males and females satisfactorily. All the estimated parameters of males and females, except the path of the MAT on math achievement, were not statistically significantly different. Furthermore, the covariance matrices of males and females were not statistically different. Hence, the proposed best-fitting model is generalizable to males and females. Interestingly, however, means of males on the three MSES scales and the MAT were significantly higher than those of females. However, the performance of males and females on the teacher-assigned mark was not statistically different. These results are similar to those reported in many previous studies (see Kimball's (1989) review and Hyde, Fennema, & Lamon's (1990) and Randhawa's (1991) meta-analysis of mathematics achievement). Randhawa, in particular, showed that males' advantage over females' could not be explained by differences in classroom behaviors. Despite observed differences and similarity in performance of males and females on the measures used in our study, math self-efficacy mediates mathematics attitude and achievement. Since the structural models of males and females in our study were similar, math achievement differences on unfamiliar tests or standardized tests might be more due to differences in math self-efficacy expectation than due to differences in structural information processing.

In the best fitting model the DS as one of the manifest indicators of the math achievement construct had the path coefficient of $-.44$. This is either a spurious value because of the LISREL solution artifact or it suggests that math achievement of our students is negatively correlated with their perception of confidence in doing everyday mathematics tasks. If the latter is a plausible explanation, then it is possible that the current mathematics curricula and the delivery do not entail appropriate links to everyday mathematical tasks (Meece, Wigfield, & Eccles, 1990). Applications of mathematical knowledge to everyday situations is possible only if the knowledge base is rich and stable and cognitive structures and schemas for doing this transfer are provided

through appropriate practice (Kintch & Greeno, 1985; Sweller, Mawer, & Ward, 1983). With explicit links to everyday applications of math, the unfamiliarity factor will be reduced. The self-efficacy judgements of such tasks as a result would differentially improve for females. These conclusions lend support to the National Council of Teachers of Mathematics' (1989) call for the student in "becoming confident in ones own ability" (p. 6) and its emphasis upon the applications of mathematics: "Even though most mathematical ideas in the K-4 curriculum arise from the everyday world, they must be regularly applied to real-world situations" (p. 18). This interest in real-world problem solving is again echoed as a feature of the middle-years program (p. 67) and the high-school program (p. 137).

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Table 1

Descriptive Statistics and the Correlation Matrix for the Seven Variables for the Total Group (n = 225)^a

Variable	Mean	s	1	2	3	4	5	6
1. CS	84.8	23.8						
2. PS	131.3	22.1	71					
3. DS	114.8	22.8	64	70				
4. ALG	68.2	15.3	52	47	23			
5. MAT	16.8	5.6	44	40	27	60		
6. MAS	64.0	7.0	38	42	30	42	28	
7. MAI	123.2	12.0	49	45	38	49	33	56

^aCorrelation coefficients are rounded off to two decimal places and the decimal is omitted. All of the correlation coefficients are significant at the .05 level.

Table 2

Correlation^a Matrices, Means, and Standard Deviations for the Seven Input Variables in Structure Modelling of Males (n = 117) and Females (n = 108)

Variable	1	2	3	4	5	6	7
1. CS		68	59	58	45	41	45
2. PS	72		69	45	33	43	42
3. DS	65	70		25	29	32	34
4. ALG	51	51	25		59	44	52
5. MAT	39	47	21	66		30	32
6. MAS	41	44	34	38	30		65
7. MAI	52	45	39	48	33	50	
Mean (M)	91.6*	133.7*	119.6*	68.1	18.2*	63.6	124.4
Mean (F)	77.3	128.0	109.0	68.7	15.6	64.7	121.8
SD (M)	21.9	21.4	20.8	16.2	6.1	7.2	11.6
SD (F)	23.7	22.8	23.9	14.9	4.9	6.5	12.3

^aThe correlations reported in the table are rounded off to two decimal places and the decimal is omitted. The triangular correlation matrix below the main diagonal is for males and that above the main diagonal is for females. All the correlations are significant, $p \leq .05$.

*Indicates that the difference between the means of males and females was significant at the .05 level.

Table 3
Squared Multiple Correlations and Intercorrelations of the Latent Variables

Variable	R^2	1	2
1. Attitude			
2. Efficacy	0.46	0.677	
3. Achievement	0.53	0.673	0.659

Figure Captions

1. Structural model of mathematics achievement showing the fixed and free parameters.
2. Completely standardized parameter estimates of the structural model of mathematics achievement.
3. Modified and parsimonious structural model of mathematics achievement indicating fixed and free parameters for structural analysis.
4. Completely standardized parameter values for the total group (above the path arrows) and common metric completely standardized parameter values for males and females from the two group solution (below the path arrows, females' values are in parentheses).







